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Are broad-leaved species useful for dating of events causing tree tilting? A critical analysis from the case of the October 1907 Brallans landslide (Central Pyrenees, Spain)

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Ring analysis of tilted coniferous trees is a valuable tool for dating a variety of natural processes (e.g. landslides, snow avalanches or earthquakes) occurred during the last centuries. This is because, on one hand, tilting is one of the most common tree disturbances caused by the mentioned processes and, in the other hand, because episodic tilting events can be easily dated in coniferous trees from the analysis of reaction wood, a wood which is formed after tilting. In broad-leaved trees, however, reaction wood is difficult to identify to the naked eye. Therefore, it seems advisable that processes causing only tilting of broad-leaved trees be dated using other tree responses like ring eccentricity or sudden reductions in ring width.

We tested the capability of the ring eccentricity analysis and abrupt reductions of growth rate to identify landsliding events. We selected the Brallans landslide, a large dormant landslide (> 5 Mm^3), close to the Turbon Massif (Central Pyrenees, Spain). Tilted trees are present all over the landslide. A reactivation event that took place in October 1907 is known from historical documents. We sampled 46 tilted oaks (*Quercus humilis*). Twenty vertical trees were sampled outside of the landslide for the construction of a control chronology.

An appropriate performance of the dating techniques would have revealed a distinct response in the ring formed in 1908, the first formed after the landslide event. However, only the 25% of the tilted trees we sampled showed a significant change of eccentricity in the ring of 1908 year. Changes of eccentricity index similar to that of 1908 occurred in many other years, the last one in 1996. Although the existence of other minor re-activation events of the landslide (not mentioned in the historical archives) occurring after that of the 1907 cannot be ruled out, the presence of mature trees standing up vertically on the slide toe indicates that the slide remained stable for the last decades. Therefore, we consider that the eccentricity analysis does not provide reliable results in the Brallans slide.

The number of abrupt growth reduction events in the Brallans slide depends on the values of the parameters used in the analysis (length of time windows and threshold value of reduction). The number reduction events (possible reactivations) may range from 22 to 1. The cases in which only one reduction event is observed, they give possible landslide reactivations in 1903 or 1904 or, only in one case, in 1908. In the latter, however, the 1908 reduction is shown only by 15% of the trees. Therefore, using these conventional dendrochronological techniques we were unable to determine the number and the exact age of the reactivations of the landslide. One reason for that is the occurrence strong climatic reduction initiated in 1904, which blurred the response of trees to the landslide event of 1907. This restriction can be overcome if the growth changes are calculated as relative to a control chronology rather than to the precedent rings. Following this approach, only three abrupt growth reductions result from the analysis, the latter one corresponding to the landslide reactivation of October 1907. In the three cases 60% of the sampled trees show a clear response. These results seem much more coherent with the available historical data.